RELATION OF SUNLIGHT TO PLANT DEVELOPMENT.

By GEORGE D. HEARN.

This paper is largely a report on experiments of W. W. Garner and H. A. Allard, plant physiologists of the United States Department of Agriculture, who have made quite complete observations on many different plants under various light conditions during the years 1918 and 1919.[1] Of the three factors entering the study, namely,

a. Intensity of light.
b. Quality of light or wave length of radiation, and
c. Duration of exposure,

the last mentioned is considered chiefly.

Considering *intensity*, it is quite generally agreed there is an optimum for each species which in most cases is less than full sunlight on a clear day. Many plants prefer direct sunlight and others indirect, as ferns, which grow in the shade of forest trees and the alga which is found on the north sides of trees. One effect of the intensity of light upon plants is well brought out when we observe a horizontal branch and a vertical branch on the same tree. On the vertical branch, if we are considering, for instance, a maple tree, the leaves will be four-ranked, i. e., in four vertical rows. The horizontal branch, while having the leaves actually attached in four rows, will have the petioles so twisted that the leaves will appear to be two-ranked, with the surfaces upturned toward the source of light. Plants grown in south windows, the appropriately named sunflower which follows the sun in its daily journey across the sky, and several "compass plants" all illustrate the effect of light intensity. In cross section, the mesophyll or middle layer cells of sun leaves display more chlorophyll bodies than do shade leaves. It is the chlorophyll or green-colored bodies which, under the influence of sunlight are responsible for the manufacture of the carbohydrate foods in plants and also the cellulose or woody material. This fact makes more understandable the blanching of celery and rhubarb and the "laying" or lodging of wheat due to the shading of the lower portions of the stalks resulting in insufficient woody material. In general a plant receiving less than its optimum of light intensity is pale, elongated, and weaker than it would otherwise be.

In regard to the *quality* of light there is not so much uniformity of opinion. White light has in general been found more favorable to plants.

The effect of the duration of *exposure to sunlight* on plants has promoted definite contributions to phenology, especially notable being that of the physiologists already mentioned. The following preliminary observation which acted as an incentive to Garner and Allard is worthy of note. "In 1906 there were observed in a strain of Maryland narrow leaf tobacco, which is a very old variety, several plants which grew to an extraordinary height and produced an abnormally large number of leaves. As these plants showed no signs of blossoming with the advent of cold weather, some of them were transplanted from the field to the greenhouse and the stalks of others were cut off and the stumps replanted in the greenhouse. These roots soon developed new shoots which blossomed and produced seeds, as did also the plants which had been transferred in their entirety. This very interesting giant tobacco, commonly known as Maryland Mammoth, which normally continues to grow till cold weather in the latitude of Washington, D. C., without blossoming, proved to be a very valuable new type for commercial purposes, but the above-mentioned procedure has been the only method by which seed could be obtained. The type bred true from the outset, and no matter how small the seed plant, the progeny have always shown the giant type of growth when propagated under favorable summer conditions."

[1] See Jour. Agr. Research, Mar. 1, 1920, 18:553-606: abstr. in Mo. WEATHER REV., July 1920, 48:415. Later note in *Science*, June 2, 1922, 55:582-583.

LENGTH OF DAY AS A FACTOR IN THE NATURAL DISTRIBUTION OF PLANTS.

Heretofore temperature, water, and light-intensity relations have been considered the chief external limiting factors governing the distributions or range of plants. The observations and experiments of Garner and Allard show that the relative lengths of the days and nights during the growing period must also be recognized as among those causes underlying the northward or southward distribution of plants. The equatorial regions of the earth alone enjoy equal days and nights throughout the year, and if water relations are favorable the warm temperatures here favor a continuous growing season for plants. Going to the higher latitudes the favorable growing temperatures are, other things being equal, limited to the summer season, which becomes increasingly shorter as we near the polar regions. On our way to the higher latitudes we find that the summers have increasingly longer periods of daylight and the winters shorter periods. It is interesting to consider how these different day-and-night relations obtaining during the summer, exercise some control upon the northward or southward distribution of plants.

Evidently a plant can not naturally persist in a region or extend its range in any direction unless conditions are favorable, not only for vegetative growth, but for reproduction as well. Seed reproduction alone is considered here. The experiments carried out by the two men already mentioned have brought out the fact that the flowering or reproductive phase of development depends upon a stimulus afforded by the shortening periods of sunlight experienced as the summer solstice is passed. Experiments with ragweed proved that when the length of day fell below 15 hours the vegetative development was checked and the blossoming or reproductive phase induced. It is thought that seeds of plants which blossomed July 1 at Washington, D. C., would not blossom until August 1 in northern Maine, because the day of less than 15 hours would not be experienced until then. If the seed were carried still farther north, the plants might not blossom at all, because the shortest days of the summer-growing period would exceed those to which they were best suited in their normal habitat. Formerly this failure to flower would be attributed to unfavorable temperature alone, but it is obvious that the length of day is the limiting factor which has retarded the reproductive period, so that unfavorable temperature has prevented the ripening of the seed.

No doubt the length of the daylight period in summer has much to do with the vegetative growth and flowering of the Arctic plants. Also, the equal days and nights of the Tropics are required for the successful existence of the indigenous flora.

In a study of the phenological aspects of different species of plants, the fact that there is a definite season for blossoming is brought out. The length of day no doubt is an important influence here. It is probable that plants which blossom when the 12-hour day is reached would become perennials in the Tropics, where the day is never much less than 12 hours.

"Since it has been shown that the stature of some plants increases in proportion to the length of the day to which the plants are exposed under experimental conditions, this factor should be expected to have some influence upon the plants in their normal habitat. In general, exceptional stature would be attained in those regions in which a long-day period allowed the plants to attain their maximum vegetative expression before the shorter days intervened to initiate the reproductive period. This condition should hold true not only for different latitudes where a plant has an extensive northward and southward range, but for different sowings in the same locality at successively later dates during the season. It is a matter of common observation that the rankest-growing individuals among such weeds as the ragweed, pigweed, lamb's quarter, cocklebur, and beggar-ticks, other conditions being equal, are those which germinated earliest in the season, and consequently were afforded the longest favorable period of vegetative activity preceding the final flowering period. It is also a matter of common observation that all these weeds, when germinating very late in the summer and coming at once under the influence of the stimulus of the shortening days, blossom when very small, often at a height of only a few inches."

In studying plants introduced from other regions, in order to determine their economic qualities, the length of day factor must be carefully considered. Dr. H. L. Shantz, plant geographer of the United States Department of Agriculture, recently brought some grasses back from equatorial Africa which in the longer day period of northern Texas attained a height of more than 20 feet, with a corresponding increase in bulk of stalk.

LENGTH OF DAY AS A FACTOR IN CROP YIELDS.

So far as is known, the length of day is the most potent factor in determining the relative proportions between the vegetative and the fruiting parts of many crop plants; and, in fact, fruiting may be completely suppressed by a length of day either too long or too short. In some crop plants the vegetative parts alone are sought, while in others the fruit or seed alone are wanted, and in still others maximum yields of both vegetative and reproductive parts are sought. It is apparent that the merits of the different varieties or strains may depend largely on the relative length of day in which they are grown, and, therefore, the date of planting may easily become the decisive factor. These are matters of vital importance to the plant breeder and the agronomist. Obviously, a delay of even two or three weeks in seeding certain crops because of inclement weather conditions or other considerations may bring about misleading results. It is to be remembered that planting too early may be equally inadvisable, for crops requiring relatively short days for blossoming may thus come under the influence of short days in early spring, resulting in "premature" flowering and a restricted amount of growth.

CONCLUSION.

Seed reproduction can be attained by the plant only when it is exposed to a specifically favorable length of day (the requirements in this particular varying widely with the species and variety), and exposure to a length of day unfavorable to reproduction but favorable to growth tends to produce gigantism or indefinite continuation of vegetative development, while exposure to a length of day favorable alike to seed reproduction and to vegetative development, extends the period of seed reproduction and tends to induce the "ever-bearing" type of fruiting.

The term *photo-period* is suggested to designate the favorable length of day for each organism.

TEMPERATURE OF AIR IN THE ICE CAVERN OF DOBSINA.[1]

By Dr. D. L. Steiner.

[Meteorological Institute, Budapest, Hungary, August 18, 1922.]

The Hungarian Meteorological Institute of Budapest has made, since November, 1911, several years' observations of the temperature in the ice cavern of Dobsina, latitude 20° 18′ 6″ E. (G. M. T.), longitude, 48° 52.2 N., elevation above m. s. l., about 980 m.

A thermograph was placed in an English instrument shelter. The automatic record from this has been regularly compared with a mercurial thermometer alongside of it. In 1912 a hygrograph was installed. Outside, in front of the cavern entrance, another instrument shelter containing a similar thermograph and a mercurial thermometer was erected. With the exception of a few interruptions due to instrumental defects, the data obtained extend to January, 1919. At the end of August, 1917, four thermometers were placed in the rocky wall of the cavern at the following depths: 0.24 m., 0.33 m., 0.44 m., and 1.08 m.

The cavern, the entrance of which faces north, forms a bag stretching downward, having the open end out and with a small aperture in the bottom. The latter leads into the crevices of the rocks. The air of the cavern has access to that outside only by means of the aperture just mentioned together with such small amounts as may pass through the capillary clefts in the rocks.

The chief results of these observations are shown in the table following:

Monthly and annual mean temperatures in the cavern and departures from outside air temperatures. (Degrees C.)

	Jan.	Feb.	Mar.	Apr.	May.	June.
Mean cavern temperature	−3.16	−2.74	−1.80	−0.90	−0.36	−0.10
Difference between cavern and outside air temperatures	+3.62	+0.54	−2.43	−3.88	−7.60	−10.44

	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
Mean cavern temperature	+0.07	+0.15	+0.21	+0.09	−0.73	−1.39	−0.89
Difference between cavern and outside air temperatures	−10.65	−11.06	−6.78	−3.39	+0.11	+0.53	−4.37

[1] Abstract from a paper presented at the Hungarian Academy of Sciences, Budapest, Sept. 13, 1922. Meteorol. Zettschr., 1922, pp. 193–199.